

## Grafting of Conductive Polymers onto the Functionalized Carbon Nanotubes

Investigator: **Baek, Jong-Beom**

Affiliation: **School of Energy Engineering, Ulsan National Institute of Science and Technology (UNIST)**

Address: **194, Banyeon, Ulsan 689-805 South Korea**

Tel: **82-52-217-2510**, Fax: **82-52-217-2019**, email: **[jbbaek@unist.ac.kr](mailto:jbbaek@unist.ac.kr)**

**Summary:** Multi-walled carbon nanotubes (MWNTs) was functionalized and used as conducting bridge in the polyaniline (PANI) matrix. Since MWNTs are exceptional materials having many advantages as follows. The one is that they assumed to have good crystalline structure and thus, they are expected to show outstanding properties. The other is that they are considered as *pseudo*-one dimensional materials with high aspect ratio (length/diameter) and thus, they are expected to display low percolation threshold. To take advantages of those features, however, they have to be homogeneous dispersion into supporting matrices without damages such as side wall opening, breaking and turning amorphous carbons. Although many researchers have been studied on carbon nanotubes (CNTs) for two decades since their discovery, a remaining challenge is still homogeneous dispersion of CNTs into individual CNT. The most of investigators have explored the easiest ways to disperse CNTs by chemical oxidization in strong acids or physical breaking by sonication. Both approaches, however, destroy carbon frameworks resulting in losing the outstanding properties of CNTs. The challenge in this proposal was covalent attachment of reactive functional groups onto the surface of MWNT with minimal damages. PANi was able to graft onto the surface of functionalized MWNT. The resultant PANi grafted MWNT displayed significantly improved electrical properties. The results of proposed project has been presented in academic meetings and published in journals. They are listed below. The rest of portions are still pursuing and the results will be published to academic journals.

### Journals

1. Jeon, I.-Y.; Tan, L.-S.; Baek, J.-B. "Grafting of Polyaniline onto the Surface of 4-Aminobenzoyl-Functionalized Multi-Walled Carbon Nanotube and Its Electrochemical Properties" *Journal of Polymer Science, Part A: Polymer Chemistry* **2010**, 48(14), 3103-3112.
2. Kang, J.Y.; Eo, S.-M.; Oh, S.-J.; Tan, L.-S.; Baek, J.-B. "Electrically conducting, thermally stable, toughest poly(2,5-benzimidazole)/carbon nanotube composite film" *Journal of Polymer Science, Part A: Polymer Chemistry* **2010**, 48, 1067.
3. Han, S.-W.; Oh, S.-J.; Tan, L.-S.; Baek, J.-B. "Grafting of 4-(2,4,6-Trimethylphenoxy)benzoyl onto Single-Walled Carbon Nanotubes in Poly(phosphoric acid) via Amide Function" *Nanoscale Research Letters* **2009**, 4, 766-772.
4. Baek, J.-B.; Lyons, C. B.; Tan, L.-S. "Macromolecular Dumbbells: Synthesis and Photophysical Properties of Hyperbranched Poly(ether-ketone)-b-Polybenzobisthiazole-b-Hyperbranched Poly(ether-ketone) ABA Triblock Copolymers" *Journal of Materials Chemistry* **2009**, 19, 4172-4182.
5. Jeon, I.-Y.; Tan, L.-S.; Baek, J.-B. "Self-Controlled Synthesis of Hyperbranched Poly(ether-ketone)s from

Report Documentation Page		Form Approved OMB No. 0704-0188
Public reporting burden for the collection of information is estimated to average 1 hour per response, including the time for reviewing instructions, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing the collection of information. Send comments regarding this burden estimate or any other aspect of this collection of information, including suggestions for reducing this burden, to Washington Headquarters Services, Directorate for Information Operations and Reports, 1215 Jefferson Davis Highway, Suite 1204, Arlington VA 22202-4302. Respondents should be aware that notwithstanding any other provision of law, no person shall be subject to a penalty for failing to comply with a collection of information if it does not display a currently valid OMB control number.		
1. REPORT DATE <b>23 AUG 2010</b>	2. REPORT TYPE <b>Final</b>	3. DATES COVERED <b>15-04-2009 to 15-04-2010</b>
4. TITLE AND SUBTITLE <b>Grafting of conductive polymers onto the Functionalized Carbon Nanotubes</b>		5a. CONTRACT NUMBER <b>FA23860914018</b>
		5b. GRANT NUMBER
		5c. PROGRAM ELEMENT NUMBER
6. AUTHOR(S) <b>Jong-Beom Baek</b>		5d. PROJECT NUMBER
		5e. TASK NUMBER
		5f. WORK UNIT NUMBER
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) <b>Ulsan National Institute of Science and Technology, 100 Banyeon, Ulsan, Korea (South), KE, 689-897</b>		8. PERFORMING ORGANIZATION REPORT NUMBER <b>N/A</b>
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES) <b>Asian Office of Aerospace Research &amp; Development, (AOARD), Unit 45002, APO, AP, 96338-5002</b>		10. SPONSOR/MONITOR'S ACRONYM(S) <b>AOARD</b>
		11. SPONSOR/MONITOR'S REPORT NUMBER(S) <b>AOARD-094018</b>
12. DISTRIBUTION/AVAILABILITY STATEMENT <b>Approved for public release; distribution unlimited</b>		
13. SUPPLEMENTARY NOTES		
14. ABSTRACT <b>Multi-walled carbon nanotubes (MWNTs) were functionalized and used as conducting bridge in the polyaniline (PANI) matrix. Since MWNTs are exceptional materials having many advantages as follows. The one is that they assumed to have good crystalline structure and thus, they are expected to show outstanding properties. The other is that they are considered as pseudo-one dimensional materials with high aspect ratio (length/diameter) and thus, they are expected to display low percolation threshold. To take advantages of those features, however, they have to be homogeneous dispersion into supporting matrices without damages such as side wall opening, breaking and turning amorphous carbons. Although many researchers have been studied on carbon nanotubes (CNTs) for two decades since their discovery, a remaining challenge is still homogeneous dispersion of CNTs into individual CNT. The most of investigators have explored the easiest ways to disperse CNTs by chemical oxidization in strong acids or physical breaking by sonication. Both approaches, however, destroy carbon frameworks resulting in losing the outstanding properties of CNTs. The challenge in this proposal was covalent attachment of reactive functional groups onto the surface of MWNT with minimal damages. PANi was able to graft onto the surface of functionalized MWNT. The resultant PANi grafted MWNT displayed significantly improved electrical properties. The results of proposed project has been presented in academic meetings and published in journals. They are listed below. The rest of portions are still pursuing and the results will be published to academic journals.</b>		
15. SUBJECT TERMS <b>Carbon nano tubes, functionalization, Nanocomposites</b>		

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT <b>Same as Report (SAR)</b>	18. NUMBER OF PAGES <b>4</b>	19a. NAME OF RESPONSIBLE PERSON
a. REPORT <b>unclassified</b>	b. ABSTRACT <b>unclassified</b>	c. THIS PAGE <b>unclassified</b>			

- $A_2 + B_3$  Approach in Poly(phosphoric acid)" *Journal of Polymer Science, Part A: Polymer Chemistry* **2009**, 47, 3326-3336..
6. Lim, J.-K.; Jeon, I.-Y.; Laufersweiler, M.; Lyons, C. B.; Tan, L.-S.; Baek, J.-B. "Carboxylic Acid-Terminated Hyperbranched Polybenzoxazole (PBO) and Its Star Block Copolymers" *Macromolecules* **2009**, 42(5), 1541-53.

## Proceedings

1. In-Yup Jeon, Jong-Beom Baek "Grafting of Polyaniline onto the Surface of Amino-Functionalized Multi-Walled Carbon Nanotube via interfacial Polymerization." MRS. 2009 fall meeting, Prepr. Boston, MA, November 30-December 4.
2. Kyung-Soo Kim, In-Yup Jeon, Jong-Beom Baek "Reinforcing Efficiency of Epoxy Resin by 4-(Aminophenoxy)Benzoyl-functionalized Carbon Nanotubes and Carbon Nanofibers." MRS. 2009 fall meeting, Prepr. Boston, MA, November 30-December 4.
3. Hyun-Jung Choi, In-Yup Jeon, Jong-Beom Baek "Stable anchoring of gold nanoparticle onto thiol-functionalized multi-walled carbon nanotube and its electrochemical properties " MRS. 2009 fall meeting, Prepr. Boston, MA, November 30-December 4.
4. Jong-Kwan Lim, Jong-Beom Baek "Purification and Functionalization of Diamond Nanopowders." MRS. 2009 fall meeting, Prepr. Boston, MA, November 30-December 4.
5. Ji-Ye Kang, Soo-Mi Eo, Jong-Beom Baek "Synthesis and Characterization of poly(2,5-benzimidazole) (ABPBI) Grafted CARbon Nanotubes." MRS. 2009 fall meeting, Prepr. Boston, MA, November 30-December 4.
6. Lim, Jong-Kwan; Tan, Loon-Seng; Baek, Jong-Beom. Purification of carbon nanopowders and diamond nanopowders in polyphosphoric acid/phosphorous pentoxide. *Polymer Preprints (American Chemical Society, Division of Polymer Chemistry)* (2009), 50(1), No pp. given. Salt Lake City, UT, United States, March 22-26, 2009.
7. Kang, Sang-Wook; Jeon, In-Yup; Tan, Loon-Seng; Baek, Jong-Beom. Doping of polyaniline by carboxylic acid- and sulfonic acid-terminated poly(ether-ketone). *Polymer Preprints (American Chemical Society, Division of Polymer Chemistry)* (2009), 50(1), No pp. given. Salt Lake City, UT, United States, March 22-26, 2009.
8. Wang, David H.; Silhn, Sangwook; Baek, Jong-Beom; Roy, Ajit K.; Tan, Loon-Seng. Vapor grown carbon nanofibers and epoxy nanocomposites: functionalization, preparation and characterization. *Polymer Preprints (American Chemical Society, Division of Polymer Chemistry)* (2009), 50(1), No pp. given. Salt Lake City, UT, United States, March 22-26, 2009.
9. Kang, Ji-Ye; Eoa, Su-Mi; Tan, Leon-Seng; Baek, Jong-Beom. Functionalization of 3,4-diaminobenzoic acid onto the surface of carbon nanotube in polyphosphoric acid/phosphorus pentoxide medium. *Polymer Preprints (American Chemical Society, Division of Polymer Chemistry)* (2009), 50(1), No pp. given. Salt Lake City, UT, United States, March 22-26, 2009.
10. Choi, Hyun-Jung; Jeon, In-Yeoup; Tan, Loon-Seng; Baek, Jong-Beom. Thiol-functionalized multi-walled

- carbon nanotube/gold nanoparticle composites. Polymer Preprints (American Chemical Society, Division of Polymer Chemistry) (2009), 50(1), No pp. given. Salt Lake City, UT, United States, March 22-26, 2009.
11. In-Yup Jeon, Loon-Seng Tan, Jong-Beom Baek "Mass production of graphene by edge-functionalization of graphite in poly(phosphoric acid)" The polymer Society of Korea 2009, 34(2), (Gwangju, October 8-9).
  12. Sang-Wook Kang, Loon-Seng Tan, In-Yup Jeon, Jong-Beom Baek "In-situ synthesis of polymeric acids doped polyaniline via oxidative polymerization" The polymer Society of Korea 2009, 34(2), (Gwangju, October 8-9).
  13. Hyun-Jung Choi, Jong-Beom Baek "Synthesis of thiol-functionalized multi-walled carbon nanotube/gold nano-particle composites and its electrochemical properties" The polymer Society of Korea 2009, 34(2), (Gwangju, October 8-9).
  14. Kyung-Soo Kim, In-Yup Jeon, Jong-Beom Baek "Reinforcing efficiency of epoxy resin by 4-(aminophenoxy)benzoyl-functionalized carbon nanomaterials" The polymer Society of Korea 2009, 34(2), (Gwangju, October 8-9).
  15. Ji-Ye Kang, Jong-beom Baek "Functionalization of 3,4-diaminobenzoic acid into the surface of Carbon nanotubes in Polyphosphoric acid/Phosphorous Pentoxide medium" The polymer Society of Korea 2009, 34(2), (Gwangju, October 8-9).
  16. Jong-Kwan Lim, Jong-Beom Baek "Purification and Functionalization of Diamond Nanopowders in Polyphosphoric acid/Phosphorous Pentoxide" The polymer Society of Korea 2009, 34(2), (Gwangju, October 8-9).
  17. Seo-Yun Bae, Eun-Kyoung Choi, Jong-Beom Baek "Exfoliation of brominated graphite into graphene via ATRP process" The polymer Society of Korea 2009, 34(2), (Gwangju, October 8-9).
  18. Jong-Kwan Lim, Jong-Beom Baek "Purification and Functionalization of Diamond Nanopowders in Polyphosphoric acid/Phosphorous Pentoxide" The Polymer Society of Korea 2009, 34(1) (Daejeon, April 9-10).
  19. Hyun-Jung Choi, Jong-Beom Baek "Synthesis and properties of gold nanoparticle/thiol-functionalized multi-walled carbon nanotube composites" The Polymer Society of Korea 2009, 34(1) (Daejeon, April 9-10).
  20. Ji-Ye Kang, Jong-beom Baek "Preparation and Characterization of PVA/MWNT and PVA/HB-MWNT Composite Films" The Polymer Society of Korea 2009, 34(1) (Daejeon, April 9-10).
  21. Sang-Wook Kang, Loon-Seng Tan, In-Yup Jeon, Jong-Beom Baek "Electrochemical properties of polyaniline doped by carboxylic acid or sulfonic acid-terminated hyperbranched poly(ether-ketone)s" The Polymer Society of Korea 2009, 34(1) (Daejeon, April 9-10).
  22. Seo-Yun Bae, Eun-Kyoung Choi, Jong-Beom Baek "Exfoliation of graphite with 4-ethylbenzoic acid in poly(phosphoric acid)/phosphorous pentoxide" The Polymer Society of Korea 2009, 34(1) (Daejeon, April 9-10).
  23. Kyung-Soo Kim, In-Yup Jeon, Jong-Beom Baek "Reinforcing efficiency of epoxy resin by 4-(aminophenoxy)benzoyl-functionalized carbon nanomaterials" The Polymer Society of Korea 2009, 34(1) (Daejeon, April 9-10).

24. In-Yup Jeon, Loon-Seng Tan, Jong-Beom Baek "Grafting of Polypyrrole onto the Surface of Amin-Functionalized Multi-Walled Carbon Nanotubes" The Polymer Society of Korea 2009, 34(1) (Daejeon, April 9-10).